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THE EFFECTS OF THE SPACE ENVIRONMENT ON TWO ARAMID MATERIALS

by

Richard L. Kiefer
Professor of Chemistry
College of William and Mary
Williamsburg, Virginia 23185

Two aramid fibers having closely related chemical structures have been chosen for important roles in the first tether to be used to connect pairs of orbiting vehicles. The protective outer jacket of the tethers will consist of woven fibers of poly(m-phenylene isophthalamide), commercially available from du Pont as Nomex. A cylindrical sheath of woven Kevlar 29, whose principal constituent is poly(p-phenylene terephthalamide), will be the load-bearing component for the tethers. The repeat units of these materials are shown in Figures 1 and 2. Both aramids have high strength-to-weight ratios, favorable thermal and chemical stabilities, and high electrical resistivities.

Orbiting tethers will be in a hostile environment in which short-wavelength electromagnetic radiation and energetic charged particles degrade exposed organic materials such as these aramid fibers[1]. At lower orbiting altitudes atomic oxygen is an especially serious hazard, since it causes rapid erosion from organic surfaces with which it comes in contact[2].

Ultraviolet radiation causes degradation of aramids through a pathway known as the Photo-Fries rearrangement in which amide linkages in the polymer backbones are broken[3]. This takes place predominately near the surface where the incident radiation has not been attenuated. Byproducts from the Photo-Fries process are uv absorbers. They form a protective skin, thus helping to reduce degradation rates. However, atomic oxygen would most likely erode this uv shield, thereby contributing to an unwanted synergism with the uv radiation.

Studies on the effects of ultraviolet radiation and atomic oxygen on fibers and films of Kevlar and Nomex are in progress. The Kevlar used in these studies is Kevlar 49, which is almost identical chemically to Kevlar 29. It was purchased in fiber form from du Pont in a spooled tow with a denier of 22,910. Type 430 Nomex, obtained from du Pont in a 1200 denier tow, was also studied. Films of both aramids were prepared.

Films of Kevlar were prepared by dissolving fibers in dimethyl sulfoxide (DMSO) containing a small amount of methanol and potassium t-butoxide. A thin layer of the solution was drawn across a glass plate, and the film formed when the plate was immersed in dichloromethane. The films were rinsed with water and air dried. Nomex films were pulled from solutions prepared by dissolving fibers in a mixture of dimethylacetamide and lithium chloride.

In an experiment to simulate the effects of atomic oxygen in space, small tows of Kevlar and Nomex were mounted in a commercial ashing device filled with oxygen at low pressure. An rf discharge in the instrument dissociated the molecular oxygen producing a strongly oxidizing atmosphere containing O(3P)[4]. Erosion was measured in terms of mass loss. The square root of the fraction of the original mass remaining after the sample had

been eroded for a period of time, t, was found to decrease linearly with t, consistent with erosion from the surface of long, thin rods. These results are shown in Figure 3. After accounting for the difference in the diameters of the Kevlar and Nomex fibers, it was found that the rates of mass loss per unit surface area were the same within experimental uncertainties for the two aramids.

Kevlar films were exposed to uv radiation in an apparatus consisting of a small vacuum chamber, 23 cm in diameter, into which a mass spectrometer and a quartz window were incorporated. Samples were exposed under vacuum with a 1000 watt xenon-arc lamp. Volatile products could be monitored with the mass spectrometer during the exposures. Transmission infrared spectra were taken before and after exposure to monitor chemical changes in the films. Initial results showed small changes in the infrared spectra which are consistent with degradation through a Photo-Fries process. Emission of volatile products was too low for positive identification.

References

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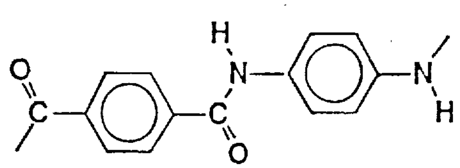

Fig. 1 The repeat unit of Kevlar

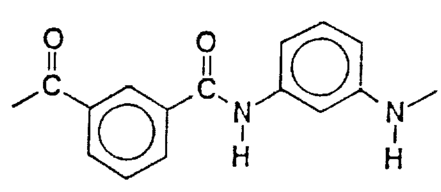

Fig. 2 The repeat unit of Nomex

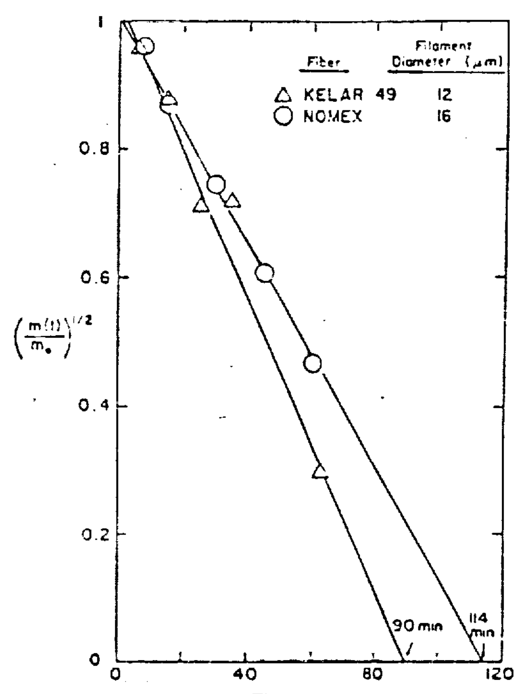

Fig. 3 Mass loss from Kevlar and Nomex fibers in an rf glow discharge chamber.